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GPO PRICE \$ _____

CFSTI PRICE(S) \$ _____

Hard copy (HC) 3.00

Microfiche (MF) _____

ff 653 July 65

N 68-26856

(ACCESSION NUMBER)

(THRU)

17

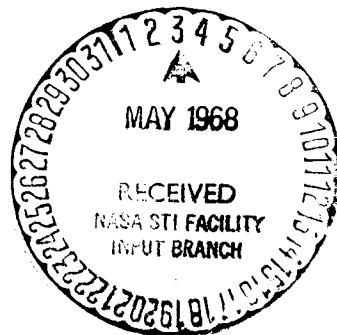
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NASA-CR-61807
(NASA CR OR TMX OR AD NUMBER)

15
(CATEGORY)



FACILITY FORM 602

SPACE DIVISION

LAUNCH SYSTEMS BRANCH

THE **BOEING** COMPANY
AERO-SPACE DIVISION
SATURN BOOSTER BRANCH

N68-26856

DOCUMENT NO. T5-6556-19

VOLUME _____ OF _____

TITLE FLUROSILICONE "O" RINGS IN GOX AT 500°F AND 1500 PSIG

MODEL NO. SAT V/S-IC CONTRACT NO. NAS8-5608

ISSUE NO. M-13

ISSUED TO

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REVISIONS			
REV. SYM.	DESCRIPTION	DATE	APPROVED

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S-406-35-11 ORIG. 1/64

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ABSTRACT

Fluorosilicone "O" rings in three sizes were tested at 500° F and 1500 psig in pure oxygen/nitrogen for five (5) minutes with a vibrational input, simulating conditions as found in an oxygen flow valve on the S-IC. Results indicated the rings did not fail from oxidation, but from mechanical attrition; leakage rates were used to determine integrity of the seal.

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1.0 OBJECT

The object of this investigation was to **subject** fluorosilicone "O" rings, such as were originally used in the 60B51441 GOX Flow Control Valve, to a high temperature, high pressure oxygen atmosphere to determine their reliability in GOX flow devices.

2.0 BACKGROUND

The S-IC Stage LOX Tank is pressurized through the GOX Flow Control Valve, part number 60B51441. This valve was designed with seals of a fluorosilicone rubber which does not meet the requirements of MSFC-SPEC-106 for LOX compatibility. Subsequently, all of these valves, except for the S-IC-501 installation, were refitted with Viton seals which are LOX compatible per MSFC-SPEC-106.

Prior to the retrofitting, several of the GOX flow control valves (with silicone seals) had been used successfully by Chrysler in static and flight firings of the S-1B stage and by Boeing during static firings of the S-IC stage.

In contrast to this behavior, the failure of silicone seals as tested per MSFC-SPEC-106 is almost complete. When impacted in liquid oxygen from 90 to 100% of the specimens will react violently.

This test was originated to obtain more information on the behavior of fluorosilicone "O" rings in a GOX environment simulating closely the GOX Flow Control Valve operating condition, i.e., 500°F and 1500 psig. Two failure modes were examined: Oxidation and Leakage.

3.0 CONCLUSION

Fluorosilicone "O" Rings as tested at 500°F and 1500 psig did not fail by oxidation.

Failure occurred by physical attrition of the ring when there was sufficient mechanical input. Without such an input the life of the ring is in excess of five (5) minutes at the given temperature and pressure. The nature of the gas, oxygen or nitrogen, had little or no effect on the mode of failure. The test results indicate that the fluorosilicone "O" ring material was adequate for this design application.

4.0 RECOMMENDATIONS

It is recommended that further efforts be made to establish limits for materials in oxygen environments on the basis of actual usage conditions.

5.0 PROCEDURE AND RESULTS

5.1 PROCEDURE

O-ring seals made from Stillman Rubber Co. TH1057 compound, a fluorosilicone material, were tested in a GOX atmosphere to determine their resistance to high-temp high-pressure oxygen. The sizes of the rings chosen were A-006, A-010, and A-034. The specimens were tested, 3 sizes at a time, in a pressurized fixture at 1500 psig and 500°F. A vibration input of 65 g's was applied to the fixture. Simultaneously, a small rotational input of 15°/min. was applied to the shaft in the fixture. Only the A-006 and A-010 size "O" rings were subjected to the rotational input. The duration of the test was five (5) minutes at temperature, ramp time not included.

A total of twelve test runs in oxygen was made, followed by four in nitrogen.

Each specimen, each tool, and each instrument, including the test fixture, was LOX cleaned according to the applicable requirements of MSFC-SPEC-164. The test fixture and test specimens were assembled in the LOX Clean Room. After several of the A-006 rings (5/16 da.) were broken in mounting a small amount of KEL-F-90 lubricant was allowed in the installation. This is a permissible lubricant for LOX cleaned systems. It was also used in the installation of the A-010 ring and the A-034 ring.

Test instrumentation included a 5000 psig Heise gauge rated at $\pm .025\%$ full scale accuracy. The accelerometer was an Endevco Model 2245, rated $\pm 5\%$. Thermocouples were rated $\pm 5^\circ\text{F}$ and were mounted (1) near the specimen, (2) in the fixture wall, and (3) in the gas cavity. (For further details see D-13185C).

The test procedure was as follows:

- 1/ The fixture was pressurized to 300 psig and depressurized five times to remove air from the test fixture.
2. The fixture was pressurized to 1500 psig and a room temperature seal leakage measurement was obtained.
3. After the specimen was pressurized to 1500 psig, the specimen was heated to 475°F.

5.1 PROCEDURES (CONTINUED)

4. When the temperature was attained, **random** vibration excitation was applied for 300 seconds. Simultaneously, shaft rotation was started. The shaft rotation was reversed every 60 seconds.
5. The temperature was maintained between 475°F and 500°F during the test run as measured on the thermocouple in the wall.
6. Vibration, heating and rotation were stopped after 300 seconds. The fixture was then permitted to cool to room temperature and a post test seal leakage measurement was obtained.
7. The fixture was disassembled. Each specimen was visually examined for evidence of deterioration due to oxidation, heat, or friction.
8. The fixture was then reprocessed through super cleaning, new specimens installed, and the fixture replaced in the test set up.
9. This sequence was continued until twelve test runs were obtained with oxygen gas and four test runs were obtained with nitrogen gas.

5.2 RESULTS

Six leakage failures (in excess of 5 SCIM) were obtained from sixteen test runs. Four of these occurred with oxygen; two occurred when nitrogen was substituted for the oxygen. This substitution was made to more clearly assess the effect of oxygen on "O" ring failure.

All rings failing were size A-006 which had the most intense mechanical loading.

It was the conclusion of all who examined these rings that none of the failures found after exposure to oxygen could be attributed to oxidation.

Regardless of atmosphere, the dynamic loading on the A-006 "O" ring (0.11 I. D.) together with temperature, caused a fretting of the ring surface, and this, coupled with the loss of small particles which had been torn from the surface, was sufficient to cause leakage failure. The two other sizes, A-010 and A-034, 0.24 and 2.1 I.D. respectively did not fail.

A slight discoloration seen on some of the rings was ascribed to the use of Kel-F 90 as a lubricant to facilitate assembly and not to oxidation of the "O" rings.

The A-034 ring, used as a static seal in the test fixture, showed no discernible mass or surface change, other than a slight extrusion due to the high pressure. The elasticity also was apparently unimpaired. Since this ring had the same exposure as the two smaller rings, with the exception of the rotational loading, it affirms the conclusion that the failure of the A-006 ring (Leakage) was caused by mechanical stress.

This conclusion is reinforced by inspection of those rings tested in nitrogen. Half of the A-006 rings so tested failed; the appearance of these rings was very similar to those failing after oxygen test; all of the failed rings showed abrasion.

6.0

REFERENCES

1. D-13185C GOX Compatibility Test "O" Rings
GOX Flow Control Valve

2. Color Photographs

Serial	Figure	Description
15,042-7C	1	New A-034 Ring
15,688-1C	2	A-034 Specimen #3 - Max temp. 467°F in GOX A-034 Specimen #4 - Max temp. 360°F in GOX A-034 Specimen #21 - Nitrogen 475 nominal
15,042-5C	3	New A-010 Ring
15,456-1C	4	Twelve A-010 Rings tested in GOX
15,456-3C	5	Four A-010 and A-006 Rings in GN ₂ . (4, 15, and 22 are the most discolored)
15,042-6C	6	New A-006 Ring
15,456-2C	7	Twelve A-006 Rings tested in GOX
15,688-2C	8	Simulated GFCV Potentiometer Shaft (As used in all tests) with a new A-006 Ring and an A-006 after test and disassembly.

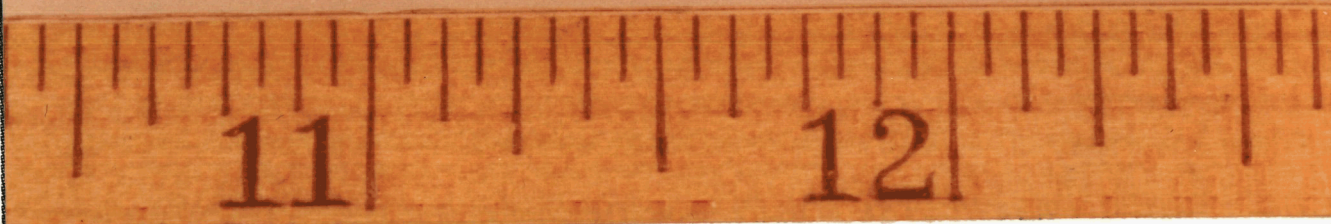
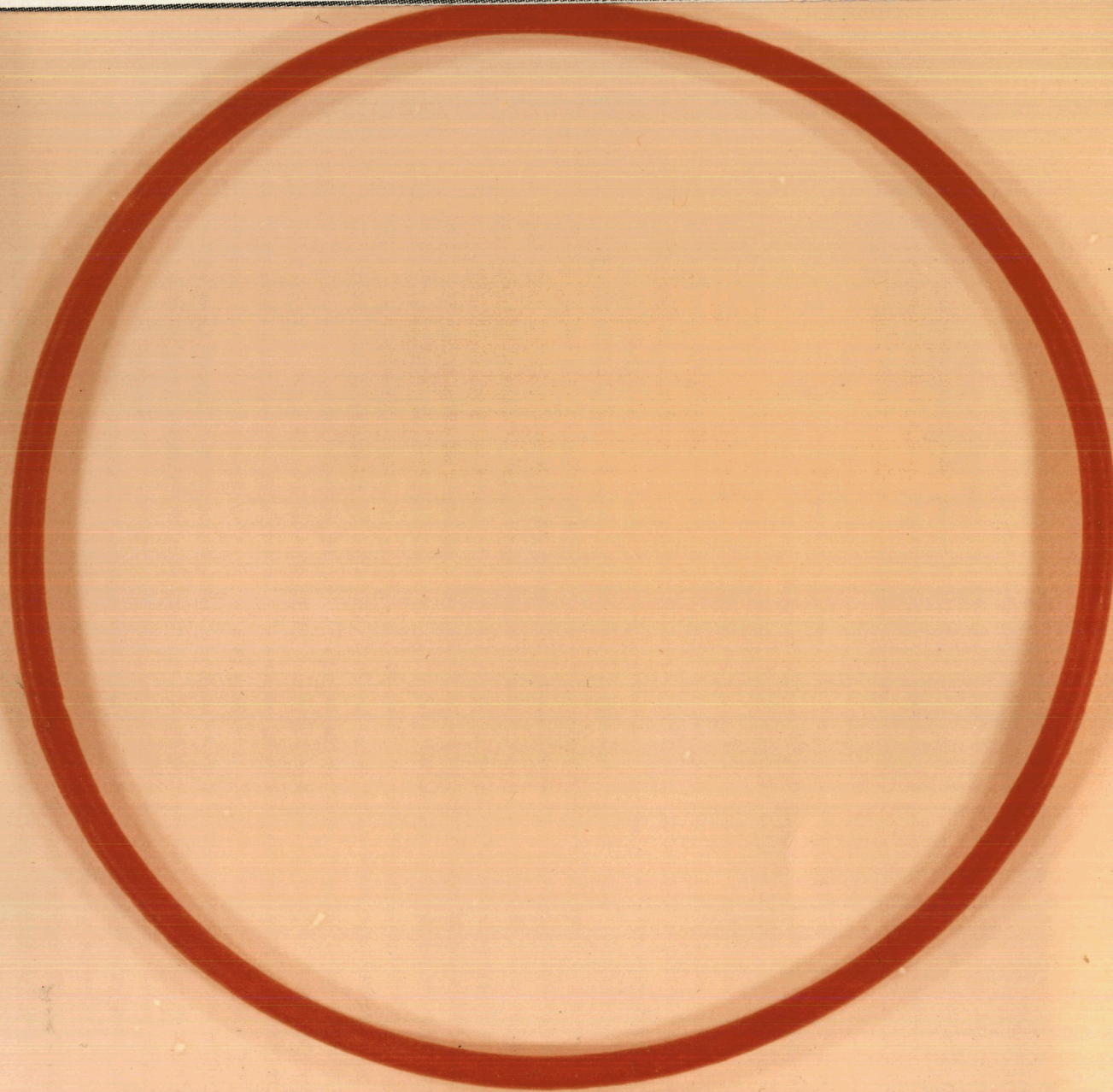


Figure 1
New A-034 Ring

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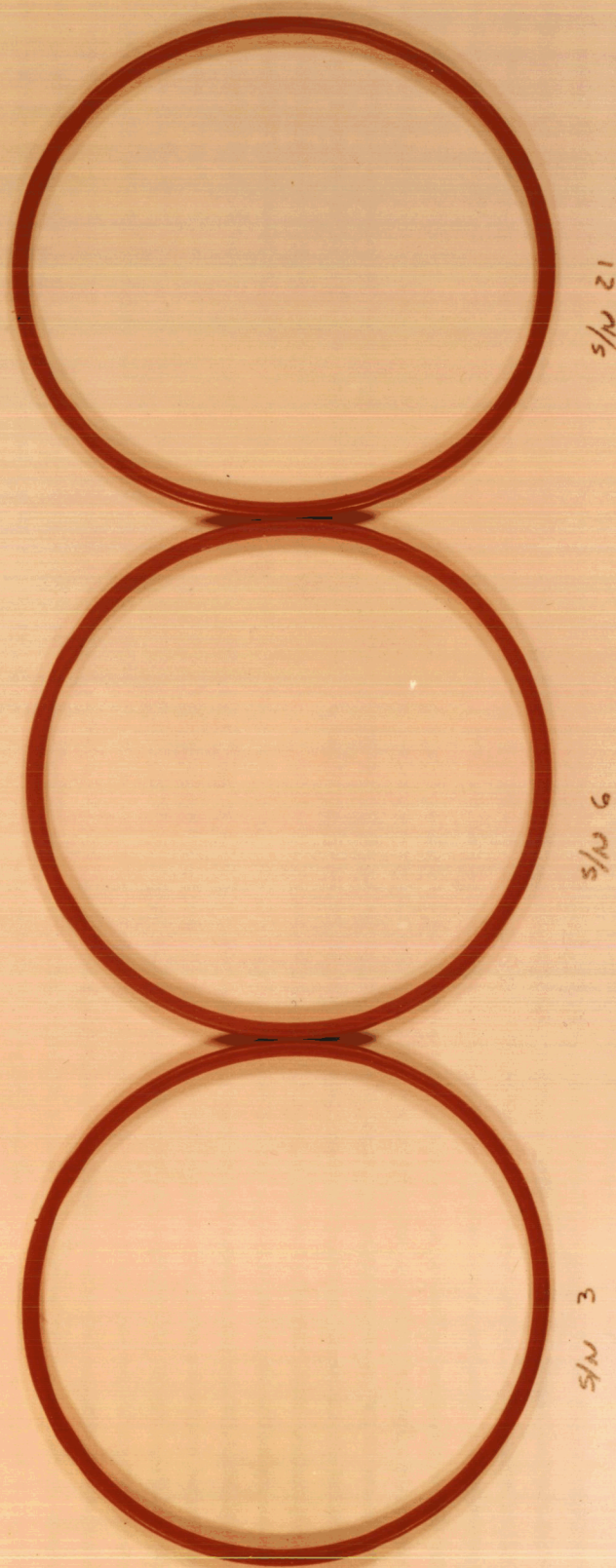


Figure 2

A-034 Specimen #3 - Max. temp. 467°F in GOX
A-034 Specimen #6 - Max. temp. 360°F in GOX
A-034 Specimen #21 - Nitrogen 475 nominal

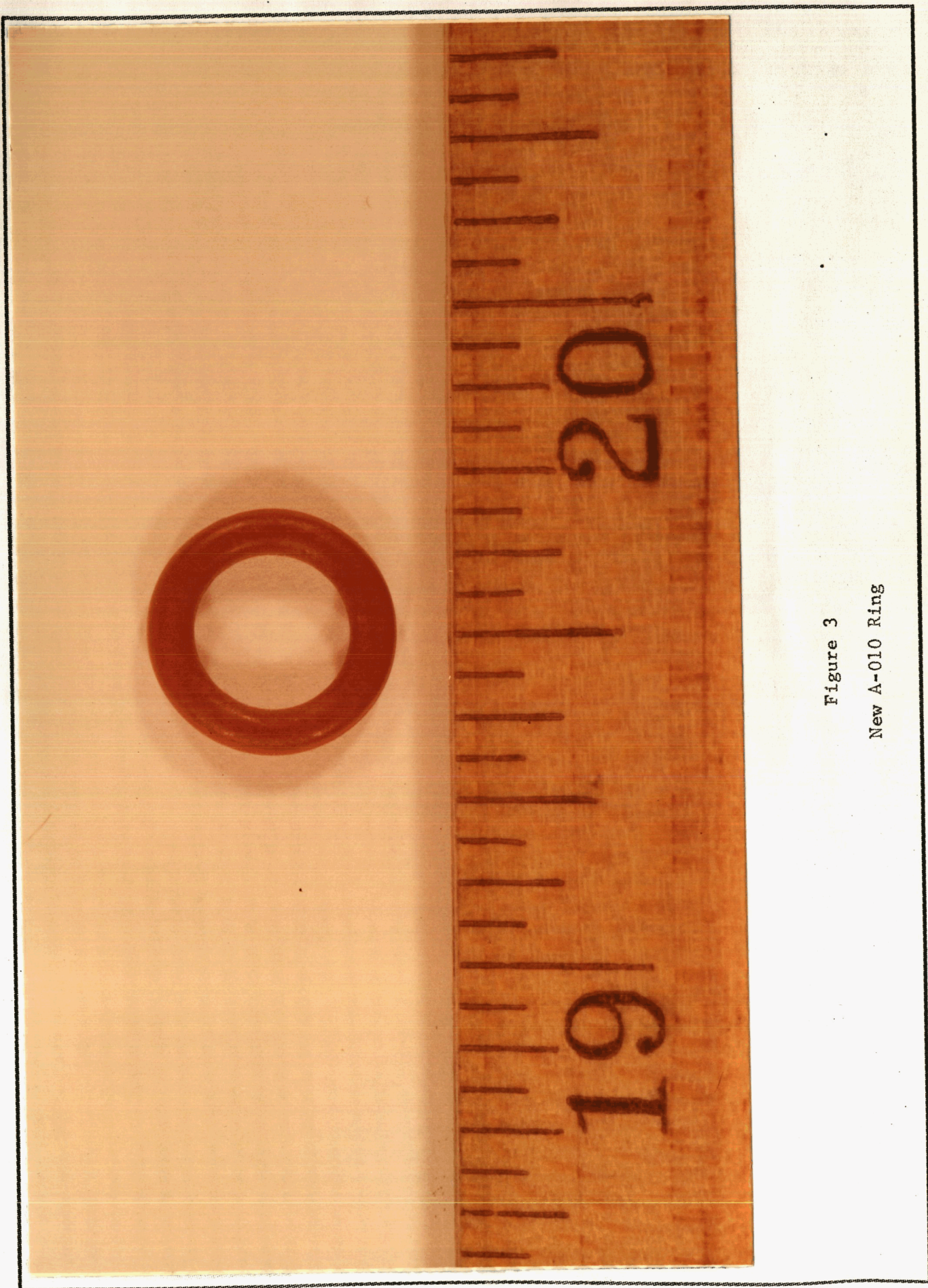


Figure 3
New A-010 Ring

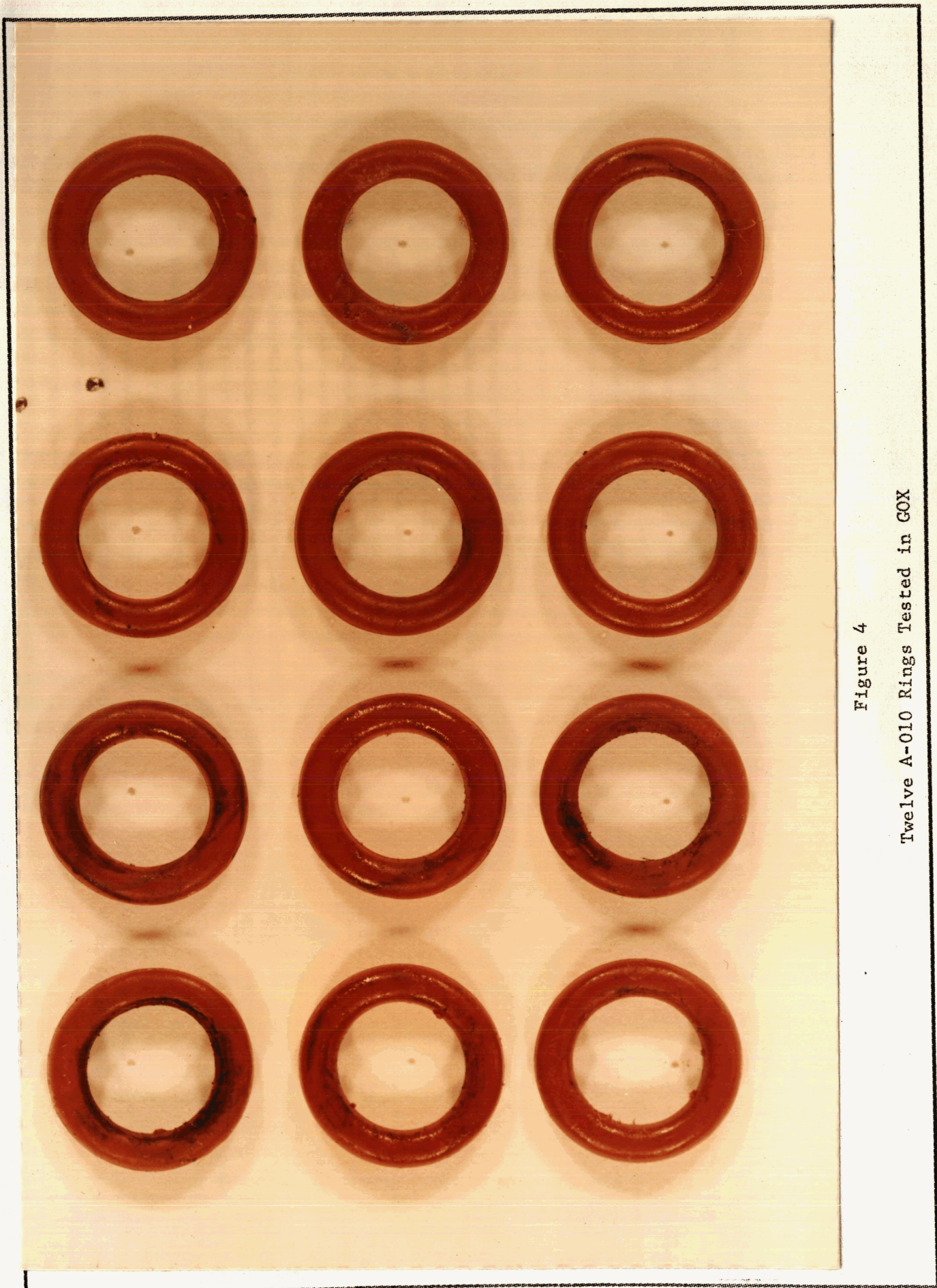


Figure 4
Twelve A-010 Rings Tested in GOX

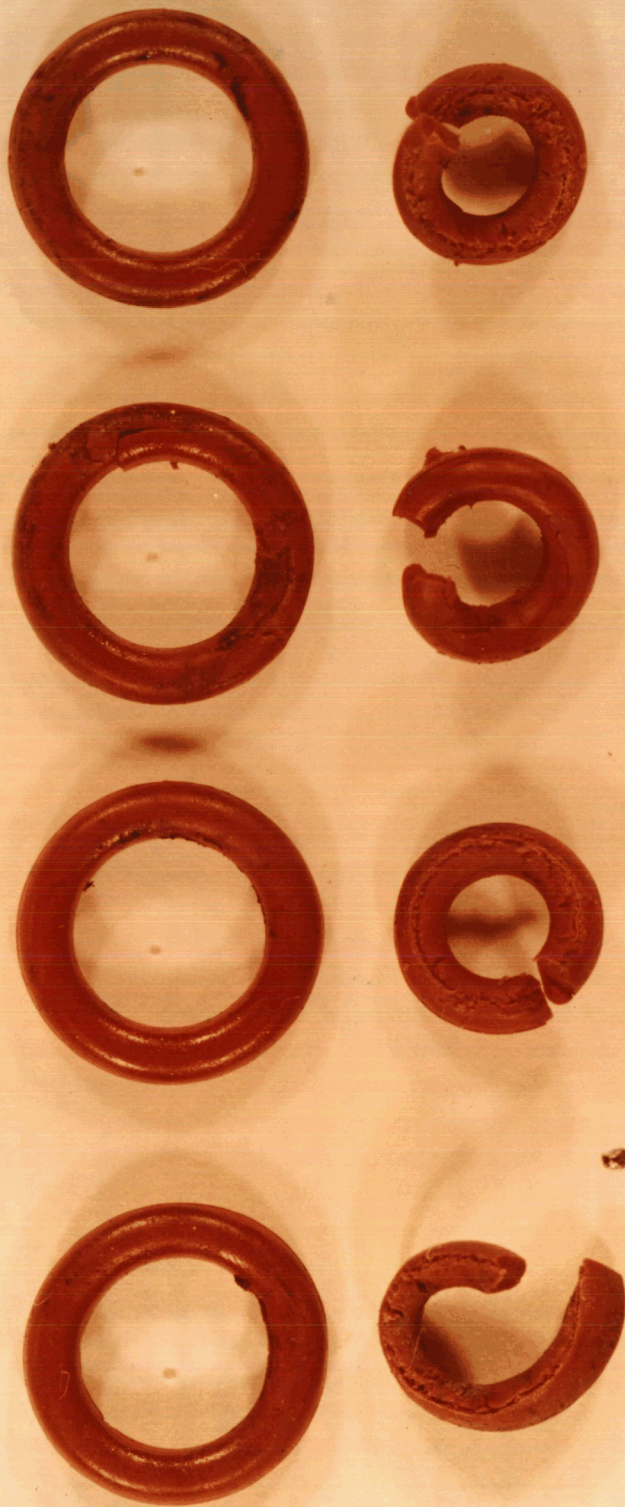


Figure 5

Four A-010 and A-006 Rings in GN2

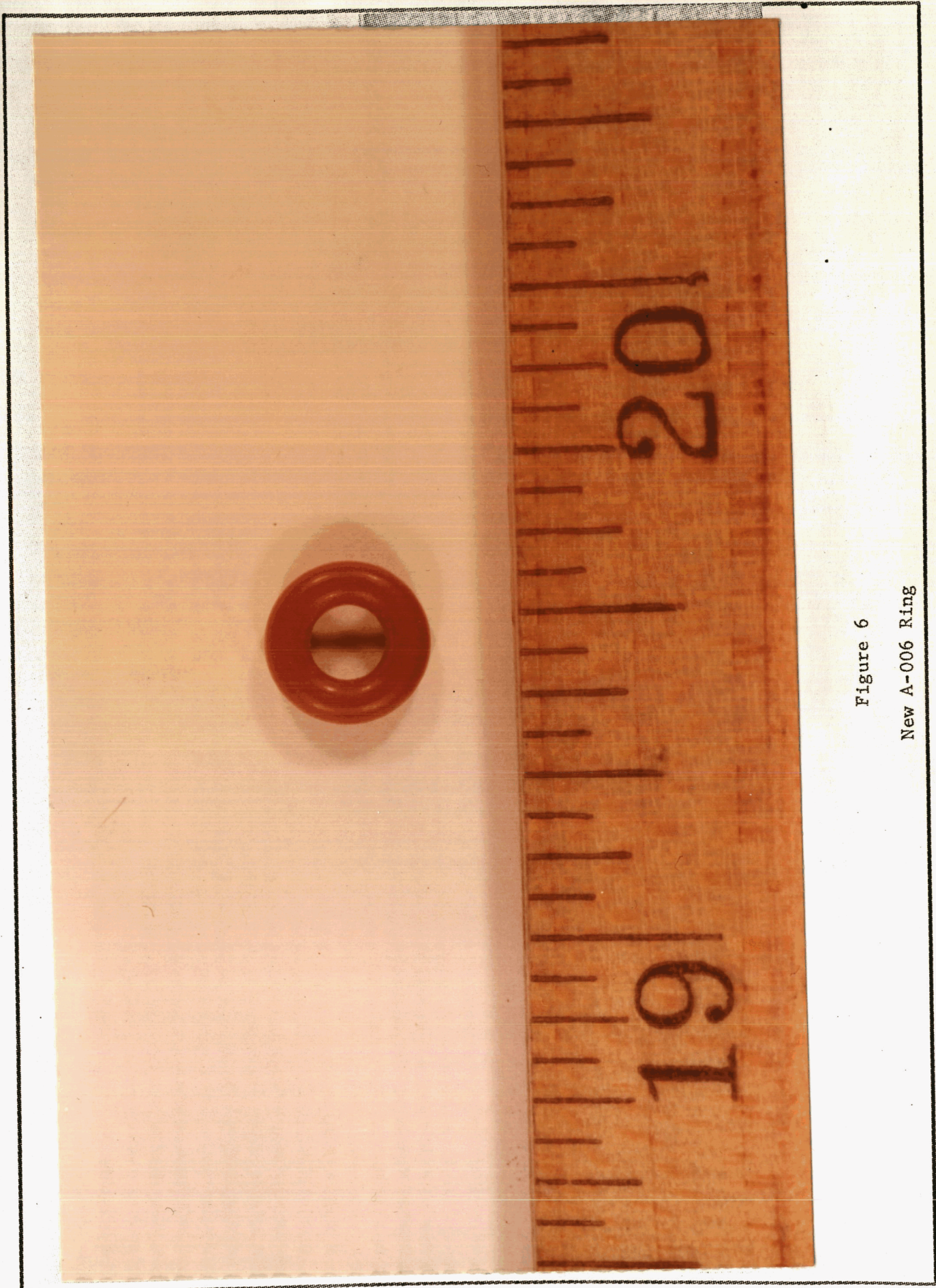


Figure 6
New A-006 Ring

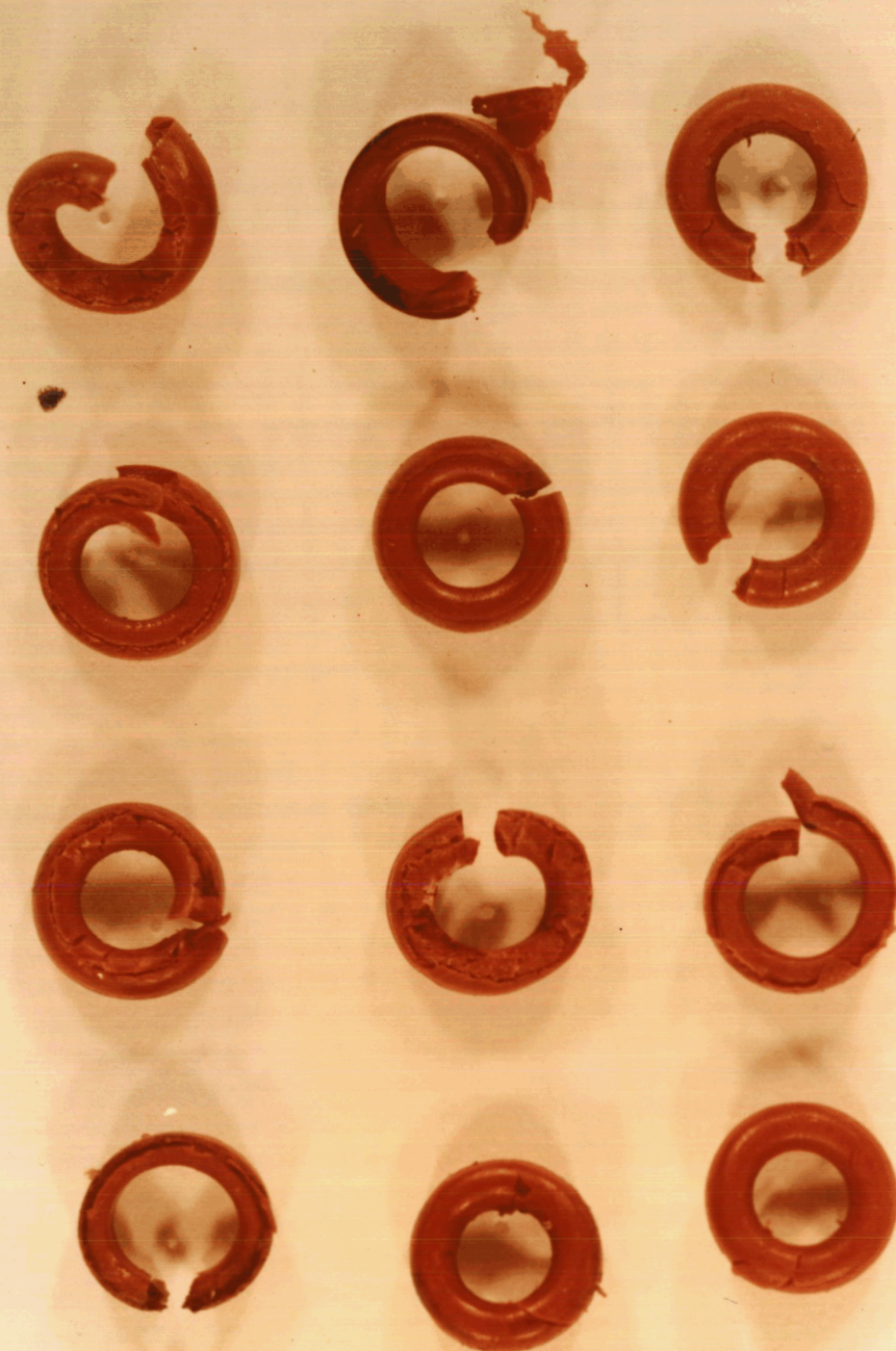


Figure 7
Twelve A-006 Rings tested in GOX

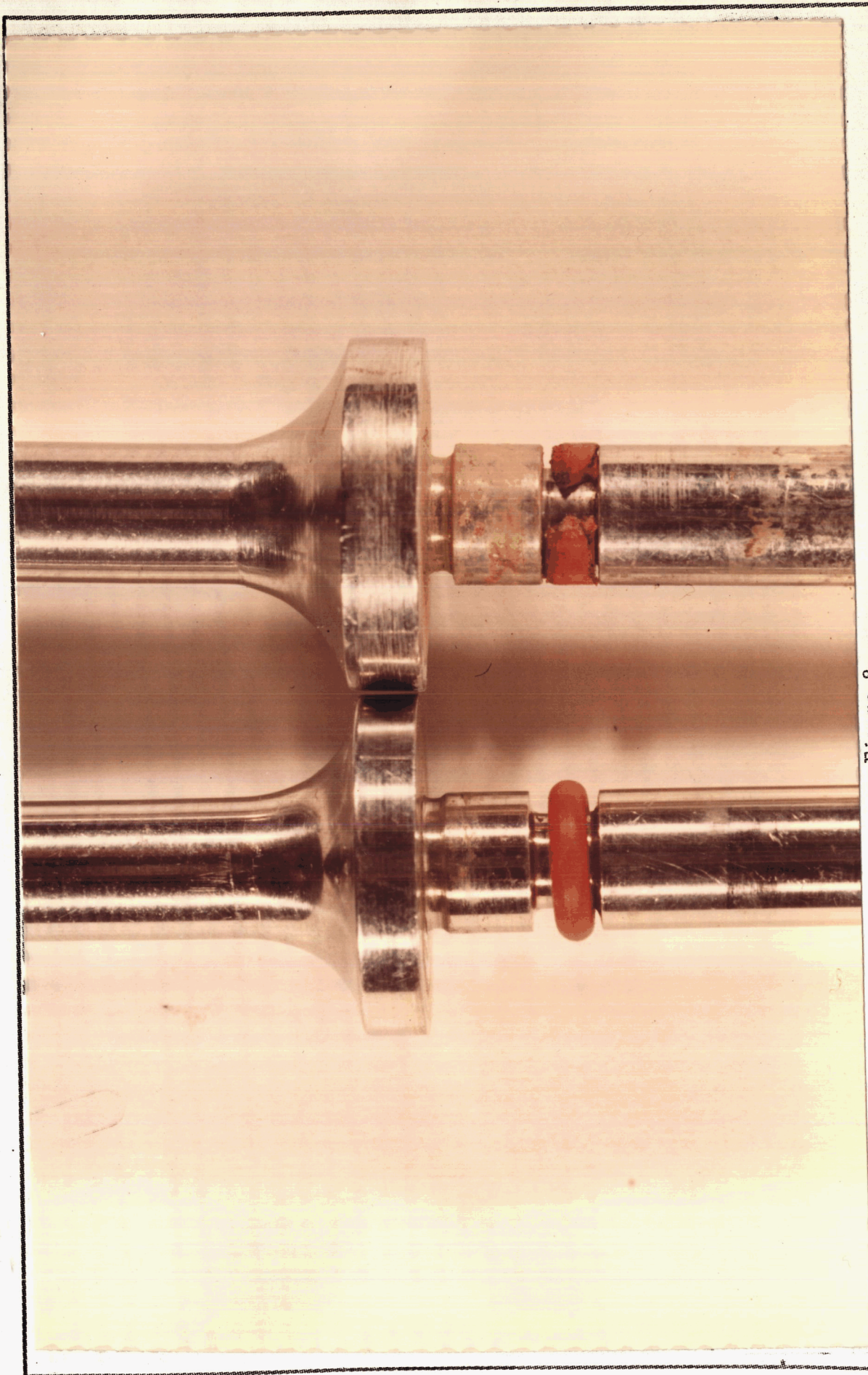


Figure 8

Simulated GFCV Potentiometer Shaft
(As used in all tests) with a new
A-006 Ring & an A-006 after test disass'y.